SEMINAR: SUSTAINABLE ACCESS
AND LOCAL RESOURCE SOLUTIONS
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TITLE: **River Morphology and Rural Route Alignments: A case study from Sri Lanka.**

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Abstract:

Failure to understand or lack of awareness of the natural dynamic behavior of alluvial river systems in deciding route alignments have caused considerable damage to the national transport network, especially when attempting to introduce artificial changes disregarding the dynamic nature of these river systems.

Road engineers have to understand that rivers are subject to morphological processes and as a result river plan forms and cross-section shapes are changed due to sedimentation and erosion processes which are temporal and spatially varied.

The alignment of the section from Totalanga to Ambatale of the Colombo – Hanwella road (Low Level Road) located within the western province of Sri Lanka is aligned almost parallel to the left bank of a major alluvial meandering river called "Kalani", flowing generally westwards. Sections of the road route are almost at the verge of being washed into the river causing considerable negative impact to the local economy.

The author in the first place has presented an economic perspective of this 50 years old road section and subsequently has presented GIS based tools and methodologies to take into account the natural behavior of such alluvial river systems in deciding road route alignments in future.

The motivation to present this paper is to bring to the notice of fellow road/highway engineers that we cannot master rivers unless we understand the close relationship between engineering and fluvial geomorphology

Key words: Fluvial Geomorphology, geomorphic approaches,

1.0 Introduction

Even though rivers have been a focus of human activities throughout ancient and modern times, as engineers we are conventionally interested in water supply, channel design, flood control, river regulation, navigation improvements etc., but it has been clear that rivers as part of nature can only be mastered, not by force but by understanding. Major aspects of hydraulics, sedimentation and fluvial processes of rivers have only become clear to us in recent years, however many more aspects are still yet to be understood.

River flow is a type of open channel flow because of the free-surfaces, all boundaries of a river are free surfaces, a fact well described by Kennedy (1982). The hydraulics and fluvial processes of rivers are far more complex than our rigid engineering channels.

Rivers normally flow in channels cut either into bedrock or in recent sediments. Rivers in bedrock tend to follow a stable course. Those in alluvium have a strong tendency to change both their position and their behavior. Failure to understand the natural behavior of alluvial river systems have lead to unfortunate and damaging, consequences especially when artificial changes are introduced into the system.

Natural river channels flowing across alluvium are seldom straight but tend to meander. It is well known that the meandering process leads to changes in channel position. Such changes may be localized, i.e. through the formation of meander cut–offs or even through gradual meander migration as shown in fig Figure 1.

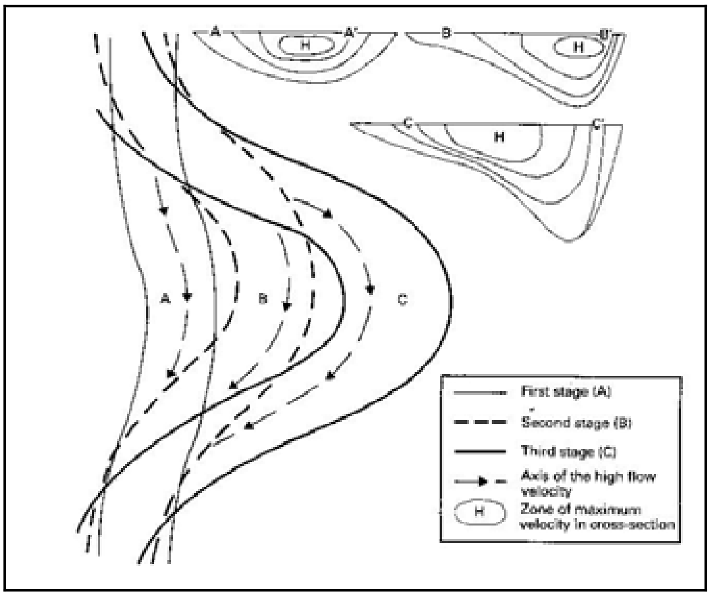


Fig 1 - Changes in channel plan form, cross section and flow characteristics in an alluvial river.

Road engineers should anticipate the above changes in any alluvial river channel, understanding that they may occur on a short as well as on a medium time scale.

The cross sectional forms of all alluvial channels can change very rapidly both in space and in time. Processes in alluvial river channels can broadly be classified into, erosion, transport and deposition. Alluvial channel deposits have been found to adopt specific forms as illustrated in Figure 2.

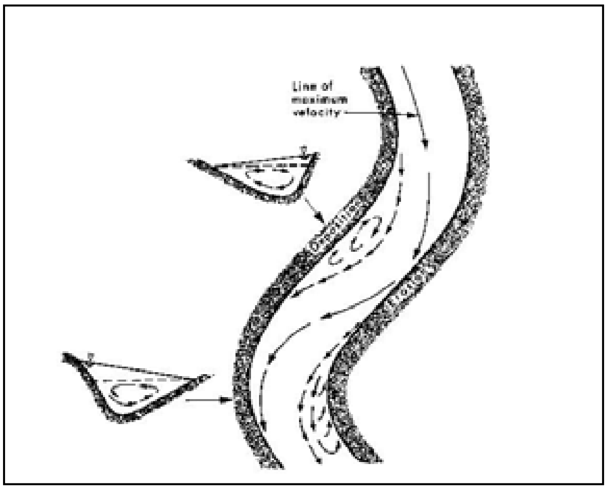


Fig: 2: Erosion, transport and deposition

1.1 The Kelani River and the Totalanga-Ambathale Road.

The Kelani River selected for this study has errodible banks and bed. There is an approximate or dynamic equilibrium between erosion and deposition, such that the channel is scoured to greater depths during floods and partly filled with sediment on falling discharge, additionally it migrates laterally and generally downstream by erosion of concave banks and deposition on banks which still maintain a similar form. The last 22km length stretch of the Kelani River prior to discharge into the sea at Totalanga meanders significantly, whereas upstream stretches are almost straight. Sections of the road now in danger are due to the movements of the channel position caused due to the gradual meander migration. See Figure 3 and Figure 4.

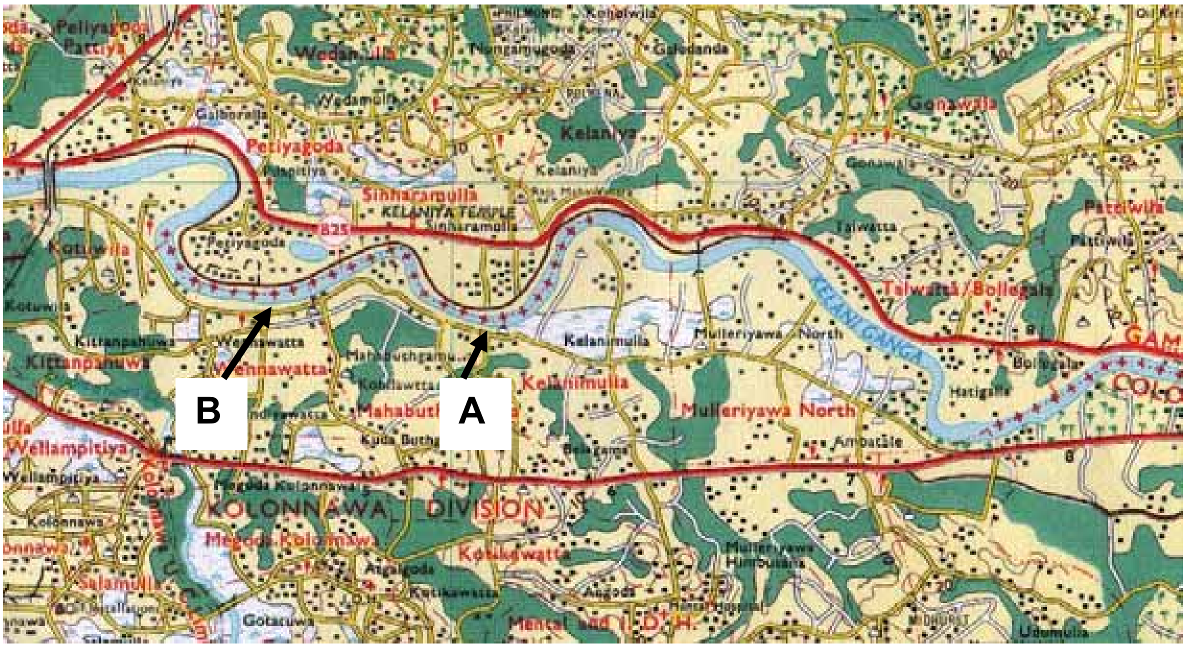


Fig 3 - Sections of the road now in danger are at locations shown at A and B.

This road is a two-way two lane road with an AADT[1] exceeding 8000 per day in both directions. During the course of the last 30 years, despite all the engineering measures taken ignoring the channel position changes and the gradual meander migration, the road today is almost at the verge of being washed away into river.

*Fig.4 - The location **B** as indicated in Fig.3 is severely affected today as indicated by the arrow.*

It is quite clear, that so far engineers have attempted to master the river only by introducing artificial measures, without understanding the close inter-relationship between river engineering and fluvial geomorphology.

This study attempts to present an application-based approach to model the temporal changes of the Kelani river channel using remotely sensed image data. The focus is placed on one aspect i.e the prediction of morphological adjustments of last 20 -25km stretch of the channel so that engineering decision making can be improved by integrating geomorphologic principals.

1 Annual Average Daily Traffic

2.0 Forms of Alluvial channels.

River channels are commonly classified as straight, meandering, braided or anastomosing, but in reality channels are complex and one river will normally exhibit several different types of channel along its entire length. Further, it may be observed that one type of channel tends to grade into another type, so changes are inevitable. Figure 5 in general illustrates the four major types of alluvial channels.

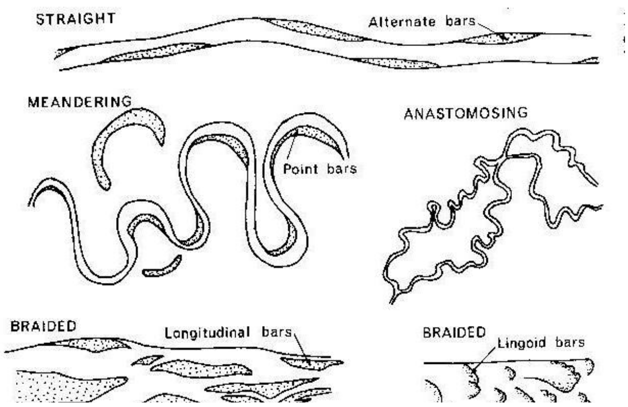


Fig 5 - The four major types of alluvial rivers.

The Kelani river channel within the study area is developing meander formation whereas upstream short stretches are almost straight, i.e. The Kelani river channel form varies down the valley and through time. Therefore river channel form changes are temporal as well as spatially varied.

Meandering rivers have sinuous channels. The sinuosity p=lc/ʎ where lc=channel length and ʎ= length of meander belt axis. The sinuosity of this section under study is approximately 2.7

Table 1 below indicates several basic characteristics of the Kelani river.

Morphology	Single river
Sinuosity	2.7
Load type	Suspension or mixed load
Bed load (% of total load)	< 40
Width/Depth ratio	< 40
Erosive behavior	Channel incision and meander widening
Depositional behavior	Point bar formation

3.0 The road section selected for study

This road section of length 8km branches off the main national road link at Ambathale and then leads to Colombo city following the left bank of the Kelani river (Figure 6).

The reason to have such a link is to have access to the potential development land strip laying between the left bank of river and the low level road. Furthermore the route facilitates traffic to exit Colombo not filtering through the city center.

This road is a two-lane two way road with an AADT exceeding 8000 per day in both direction (see figures 7 and 8). The pavement is constructed out of single size aggregate base course and the carriageway width is 5.5m with diminishing RHS shoulders (see Figure 9).

Fig.6 - Scanned image of the topographic map with the road under study indicated.

Fig.7 - General cross section of the busy road.

Fig.8 - No LHS side drains throughout the road.

Fig.9 - The diminishing RHS shoulder.

Fig10 - Road furniture, trees, telegraph posts etc. on RHS are gradually leaning towards the river.

4.0 Recent major failures and remedial measures taken.

As indicated in Figures 3 and 4 at location B, part of the road was washed away due to the gradual meander migration. In 1992 the remedial measure taken was to install a series of sheet piles which were eventually lost to the river mainly because the complex hydraulics and fluvial processes of the river were not studied sufficiently.

Subsequently as indicated in Figure 3 at location A, a large section of the road was washed away again due to meander migration in the year 2005, causing a cessation of traffic movements for several weeks. On this occasion the remedial measure taken was again to install a series of sheet piles as indicated in Figures 11 and 12. The estimated cost of this work was SLRs 950,000.00 but the actual cost has escalated to exceed SLRs 1350,000.00 and the work is not yet completed.

Fig.11 - Row of sheet piles at the apex of the meander "A"

Fig.12 - The whole investment is a loss.

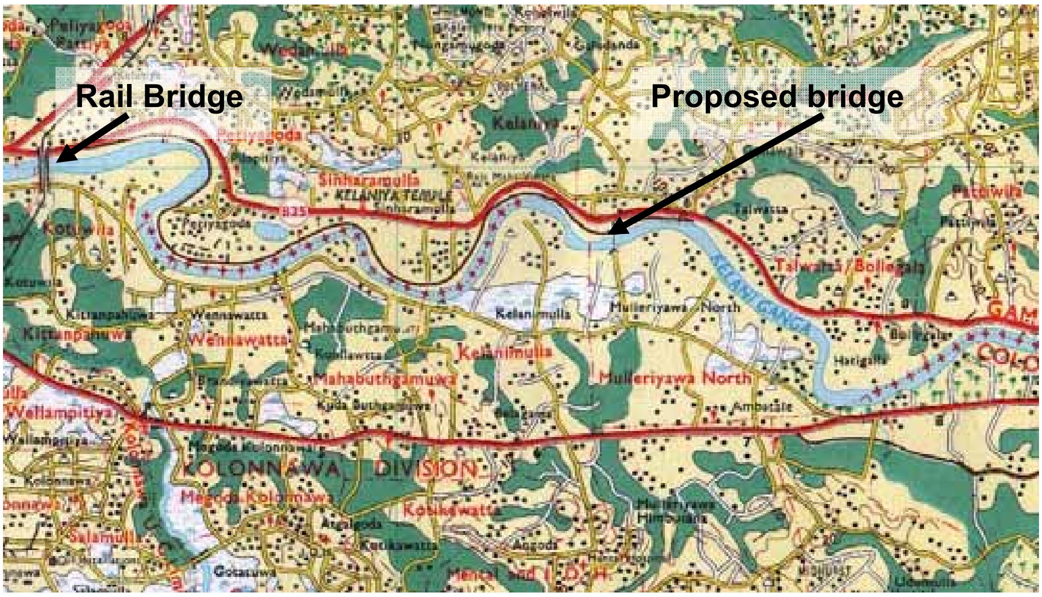
5.0 Alternative alignments and alternative transport modes.

a) As depicted in the Figure 13, it is clear that all road links either side of the river, especially within the 20 -25kms of corridor studied are located close to the banks and are in danger because of the ongoing dynamic meandering processes.

Fig. 13 - The national roads No B25 and B1 together with other rural links are in danger

b) Accordingly there is very limited scope for further road widening or to improve the existing road section under this study. Unless an engineering approach integrated with morphological principals is adopted, this road section may have to be abandoned for another alignment (with high cost and considerable landowner disruption), or even a ferry service could be operated between nodes A and B. Meanwhile the preferred option is to provide an engineering solution based on the existing route integrated with morphological principals to combat further bank erosion so that the road may be safeguarded and residential dwellings secured for safer habitation.

c) There are only two existing road bridges to cross over this section of the geomorphologically active river, one at Totalanga where the river discharges into the sea, and other approximately 22km upstream. It is proposed to construct at least one more crossing as shown below; such a new link could improve traffic flow options and provide flexibility in case of further road closures on either river bank. The siting of such a bridge justifies careful morphological investigations.



6.0 GIS based approach to monitor the river channel changes.

The ultimate objective of most GIS (Geographic Information System) based projects is to combine spatial data from diverse sources together in order to describe and analyse interactions and to make predictions with models to provide support for decision-makers. With respect to road engineering applications, GIS is commonly used to select the most suitable site or zone to satisfy a defined set of criteria. The objective of this study is to predict the morphological adjustment of river channels so that economically sustainable decisions could be taken when it is required to support investment on the roads affected.

One option for predicting morphological adjustments of river channels is to extrapolate rates and trends of change from historical records. These might include successive editions of large-scale maps, sequences of aerial photographs or remotely sensed images, past river channel surveys and other information archived by the river governing authorities.

Potential of multi-temporal remote sensing data acquired from different sensing can satisfactorily be used in investigating and assessing the future for migration of the Kelani river. In this regard historical satellite information is invaluable in assessing the most stable as well as the most vulnerable stretches, so that determination of suitable rural road alignments and bridge sites can be achieved in an economically desirable manner. In addition to the present trends of channel formation, spatial distribution of sedimentation observed by satellite data may infer the current sedimentation activities and future channel developments.

The author intended to carry out a multi-temporal image integration to investigate and to detect the pattern of erosion and deposition, and spatially variability of the Kalani River channel in its flood plain. But due to the non-availability of multi-temporal remotely sensed images at the disposal of the investigations, it has not been possible to continue this study according to the methodology outlined above.

7.0 Conclusion

Because of the close interrelationship between river engineering and fluvial geomorphology, geomorphic approaches have to be integrated with engineering principles in arriving at desirable and sustainable solutions. Understanding of channel dynamics is critical to any prediction of how the channel may evolve naturally or adjust to human impacts in the future.

The Kelani River being a geo-morphologically active river system, comparing channel widths and calculating rates of lateral migration using large scale maps of different ages should have been a continuous management strategy of the concerned road authorities. In this regard aerial photographs are less useful in yielding morphological information on river channel itself. Accordingly our design approaches and maintenance strategies should integrate geomorphic approaches in arriving at decisions.

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